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Taxonomy of North American Fish Eimeriidae

Steve J. Upton, David W. Reduker, William L. Current, and Donald W. Duszynski

August 1984

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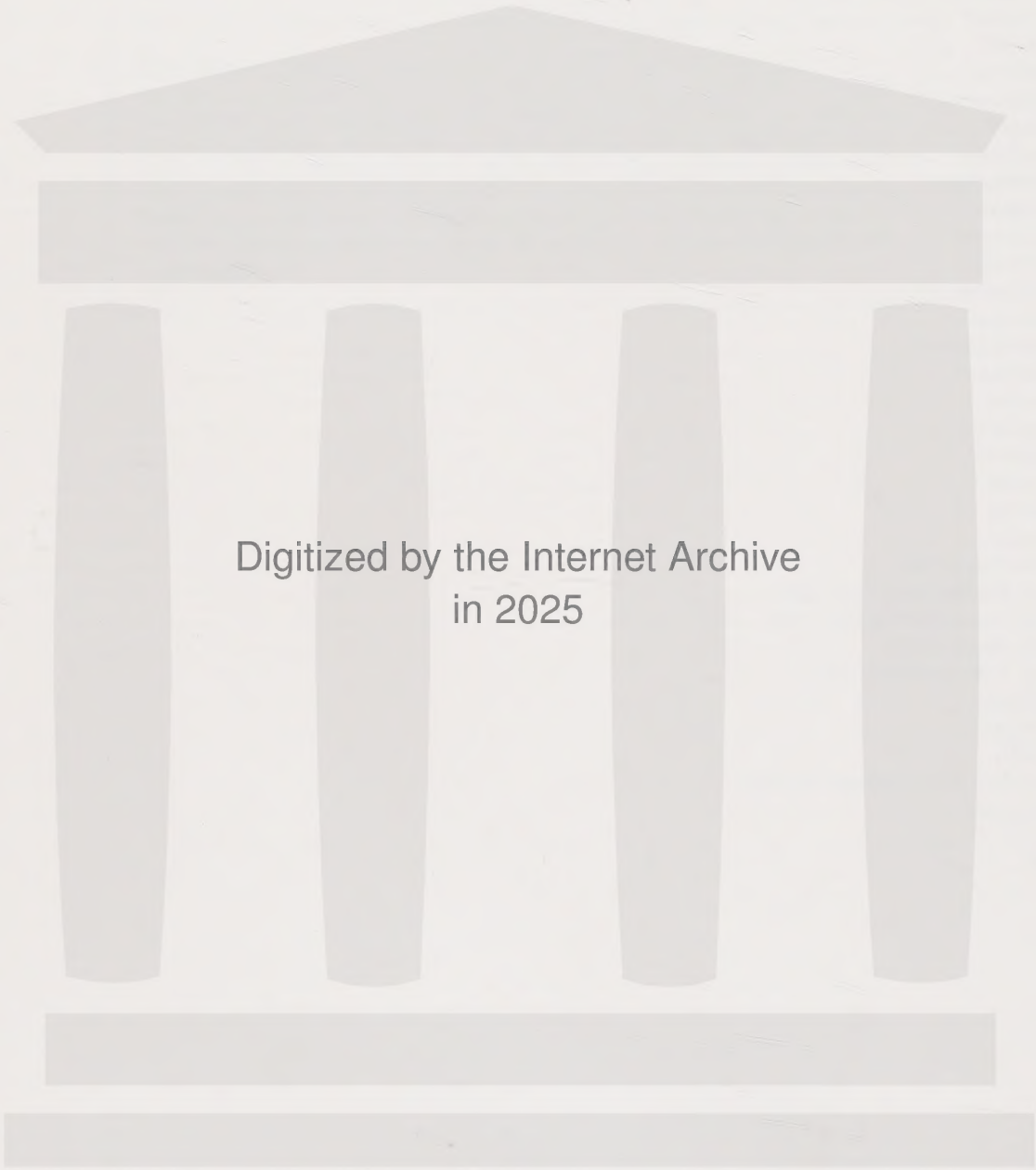

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Taxonomy of North American Fish Eimeriidae

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ABSTRACT

Taxonomic descriptions, line drawings, and references are given for the 30 named and 5 unnamed species of North American fish Eimeriidae. In addition, a key was developed based on available morphologic data to distinguish between similar species. Taxa are divided into two genera: *Eimeria* (27 species) which are tetrasporocystic with dizoic, nonbivalved sporocysts, and *Goussia* (3 species) which are tetrasporocystic with dizoic, bivalved sporocysts that lack Stieda bodies and have sporocyst walls composed of two longitudinal valves.

INTRODUCTION

The phylum Apicomplexa Levine, 1970, comprises about 4,000 species of totally parasitic protozoa which include the gregarines, haemogregarines, coccidia, malaria, and piroplasms (see Levine 1982 for taxonomic review). The largest family in the phylum is the Eimeriidae Minchin, 1903, which contains nearly 1,400 named species; over 75% of which belong to a single genus *Eimeria*.

Traditionally, genera within the Eimeriidae have been classified according to the number of sporocysts within the oocyst and the number of sporozoites within the sporocysts. The *Eimeria* are characterized by an oocyst which contains four sporocysts, each with two sporozoites.

Most Eimeriidae are species (or at least genus) specific and have similar life cycles. After an appropriate host ingests a sporulated oocyst, sporozoites are released into the intestinal lumen by the action of digestive enzymes and bile salts upon the oocyst and sporocysts. Sporozoites of most species enter intestinal epithelial cells where they reproduce asexually by merogony (schizogony), forming numerous merozoites by multiple fission. Usually merozoites enter new host cells and initiate one or more merogonous cycles. The number of asexual generations is believed to be genetically determined and the last generation merozoites invade new host cells to form gamonts. Most gamonts enlarge without karyokinesis into macrogametes, while others undergo multiple fission giving rise to numerous flagellated microgametes. When released, microgametes apparently fertilize macrogametes and the resulting zygote forms an oocyst wall to protect it from adverse environmental conditions. Usually, oocysts are passed out of the host unsporulated. Under the appropriate conditions of oxygen, temperature, and moisture, sporulation will occur and the sporulated oocyst is then infective for the next host via fecal-oral contamination. Thus, most Eimeriidae develop directly (utilize one host) and produce self-limited infections.

About 130 named species and over two dozen unnamed species of fish coccidia have been reported. All of these species except three, *Cryptosporidium nasoris* Hoover, Hoerr, Carlton, Hinsman, and Ferguson, 1981, from a naso tang; *Sarcocystis salvelini* Fantham and Porter, 1943 from a trout; and *Sarcocystis* sp. Fantham and Porter, 1943 from an eel pout, have been placed within the *Eimeria* (Fantham and Porter 1943; Hoover et al. 1981).

Although little is known about the life cycles of fish coccidia, most developmental stages appear morphologically similar to the more well known species infecting higher vertebrates. However, two important differences can be noted for the coccidia of fish. First, about one-third of the species of fish coccidia develop and sporulate in nonintestinal sites and apparently remain in situ until the host dies. Second, whether oocysts remain in host tissues or exit via the feces, fish coccidia usually sporulate endogenously and, presumably, are immediately infective when they contact the external environment. Although the significance of these peculiarities is not known, readers are directed to a recent review by Dyková and Lom (1981) for an excellent overview of the biology of fish coccidia.

Virtually nothing is known about the incidence of fish coccidia in North America and little is known about the impact that these coccidia have on their fish hosts. Solangi and Ogle (1981) reported lower weight gains for killifish infected with the hepatic coccidium *Eimeria funduli* than for uninfected, control fish. Odense and Logan (1976) believed heavy swim bladder infections of *Goussia gadi* might interfere with the ability of haddock to spawn. In other countries, however, some fish coccidia have been shown to be economically important pathogens. *Eimeria sinensis*, *E. subepithelialis*, and *Goussia carpelli* may cause enteritis and death of commercially reared carp (Molnar 1979; Dyková and Lom 1981). New Zealand eels infected with *E. anguillae* may become emaciated and weak (Hine 1975). Sterility can result in male clupeids infected with the testicular coccidium *E. sardinae* (Pinto 1956). MacKenzie (1981) has reported that an unnamed species of hepatic coccidium causes blue whiting to weigh less than uninfected fish of similar age.

Recently, Dyková and Lom (1981) have split the *Eimeria* of fish into four genera based on available morphologic and life cycle data. These include: 1) *Eimeria*, which retains most of the species and is characterized by being tetrasporocystic with dizoic, nonbivalved sporocysts with or without Stieda bodies; 2) *Goussia* Labbé, 1896 containing about 20 species which are tetrasporocystic, dizoic, lack Stieda bodies, and have sporocyst walls consisting of two valves joined by a longitudinal suture (Dyková and Lom 1981; Lom and Dyková 1982a, b); 3) *Crystallospora* Labbé, 1896 contains a single species, *Crystallospora cristalloides* (Thélohan, 1893) Dyková and Lom, 1981, which is tetrasporocystic, dizoic, and has dodecahedral sporocysts composed of two

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hexagonal, pyrimidal valves joined at their bases by a suture; and 4) *Epieimeria* Dyková and Lom, 1981 which was created for those tetrasporocystic, dizoic Eimeriidae of fish that possess Stieda bodies and undergo merogony and gametogony on the lumenal surface of the intestinal tract; three species are included in this genus (Dyková and Lom 1981; Lom and Dyková 1982a).

Innate problems exist with portions of this classification scheme; particularly for those unfamiliar with the pecularities of fish coccidia. *Crystallospora* has been reported only once, and only briefly, since the original description in 1893 (Dogiel 1948). We believe a more accurate and up to date description is needed to retain this genus. Some species (e.g., *Eimeria anguillae* Léger and Hollande, 1922 and *Eimeria hexagona* Lom and Dyková, 1981) also appear hexagonal in cross section and, thus, the only difference between the sporocysts of *Crystallospora* and those of several other species is the location of the suture. A more detailed examination of the sporocyst, particularly in the placement of the suture, is needed before the use of the genus *Crystallospora* can be warranted.

The *Epieimeria*, which are probably not epicellular but rather develop in a parasitophorous vacuole on the lumenal side of the endothelium, require histological and cytological examination to differentiate them from the *Eimeria*. Additionally, *Eimeria pigra* Léger and Bory, 1932, a coccidium infecting the intestinal epithelium of the rudd, *Scardinius erythrophthalmus*, not only develops "epicellularly," but occasionally intracellularly and lacks a Stieda body, unlike other *Epieimeria*. This genus also requires additional research to warrant proper recognition.

Pellérdy (1974) provided descriptions of most of the known fish coccidia through 1970. Since then, many new species have been reported. Because of the numerous species of fish coccidia, and because many of the original descriptions are in languages other than English, a detailed summary of each species is beyond the scope of this paper. Instead, our purpose is to provide succinct taxonomic descriptions of the known Eimeriidae from North American fish and to provide line drawings and original references that would be beneficial. These are presented below, along with literature known to us on North American fish coccidia. Taxa are divided into two genera, *Eimeria* and *Goussia*, and a taxonomic scheme is presented that we believe provides for rapid and accurate means of diagnosing fish coccidia.

TAXONOMIC DESCRIPTION

Eimeriidae Minchin, 1903

Genus *Eimeria* Schneider, 1875

Oocysts contain four sporocysts, each with two sporozoites; Stieda body may or may not be present; sporocyst wall non-bivalved.

Eimeria anguillae Léger and Hollande, 1922 (Fig. 1)

Synonyms: *Eimeria* sp. Hine and Boustead, 1974; *Epieimeria anguillae* (Léger and Hollande, 1922) Dyková and Lom, 1981.

Hosts: *Anguilla anguilla* "European eel," *A. australis* "short-finned eel," *A. dieffenbachii* "longfinned eel," *A. rostrata* "American eel" (Anguilliformes) (C[3]).

Description: Oocysts spherical, 9.8 (9.1-10.4) (see footnote 3). Wall smooth and colorless, composed of a single layer ≈ 0.1. Micropyle, polar granule, and oocyst residuum absent. Sporocysts ovoid, hexagonal in cross section, 7.8 by 4.1 (7.5-8.0 by 3.9-4.4), in contact with oocyst wall. They are usually arranged so that parallel pairs of sporocysts cross each other. Wall thin, ≈ 0.2; Stieda body present, formed by 4 papillae situated at tapered end of sporocyst. Sporocyst residuum present, spherical or ellipsoid, compact, 2.3 by 1.6 (1.9-2.6 by 1.3-1.9). Sporozoites vermiform, reflexed at one end, 6.8 by 1.5 (6.5-7.0 by 1.3-1.8) (without reflexed portion), arranged head to tail in sporocyst. Refractile bodies absent.

Sporulation: Endogenous.

Geographical locations: Corsica; New Zealand; Quebec, Canada.

Location in host: Anterior intestinal epithelium; feces.

References: Léger and Hollande (1922); Schulman and Shtein (1962); Molnar and Hanek (1974); Hine and Boustead (1974); Hine (1975); Dyková and Lom (1981).

Remarks: Merogony and gamogony occur on the lumenal border of the endothelium in the anterior portion of the intestine. The description is based predominately on that given by Molnar and Hanek (1974).

Eimeria aurati Hoffman, 1965 (Fig. 2)

Host: *Carassius auratus* "goldfish" (Cypriniformes) (F).

Description: Oocysts ovoid, occasionally spherical, 20.1 by 16.3 (16.0-24.0 by 14.0-17.0). Wall thin, ≈ 0.3. Micropyle, polar granule, and oocyst residuum absent. Sporocysts ellipsoid, 11.0-13.0 by 6.5-8.0. Stieda body and sporocyst residuum absent. Sporozoites sausage-shaped, 10.0-13.0 by 2.0-2.5, lying lengthwise and nearly filling the sporocyst entirely. Refractile bodies absent. Older oocysts may contain free sporozoites.

Sporulation: Exogenous.

Geographical location: Pennsylvania, U.S.A.

Location in host: Anterior intestinal epithelium; feces.

Reference: Hoffman (1965).

Remarks: Unsporulated oocysts were numerous in long, whitish, opaque fecal casts.

Eimeria brevoortiana Hardcastle, 1944 (Fig. 3)

Host: *Brevoortia tyrannus* "Atlantic menhaden" (Clupeiformes) (M).

Description: Oocysts spherical, 25.1 (17.5-30.0), or occasionally ovoid, 26.2 by 22.7 (21.2-30.0 by 15.0-27.5). Micropyle absent; oocyst residuum described but not depicted. A polar granule is not described or depicted. Sporocysts elongate, 16.4 by 6.3.

[3]All measurements are in micrometers (μm). Abbreviations: (B) brackish water; (C) catadromous; (F) freshwater; (M) marine.

Sporocyst residuum small; a Stieda body is not described. Sporozoites cigar-shaped, slightly curved, 15.0 by 2.5 and arranged head to tail within the sporocyst. Each sporozoite contains a large, centrally located nucleus and (possibly) a small, anterior, refractile body.

Sporulation: Endogenous.

Geographical location: Beaufort, North Carolina, U.S.A.

Location in host: Testes.

Reference: Hardcastle (1944).

Remarks: Hardcastle (1944) found that merogony and gamogony occurred in the endothelium of the pyloric caeca of both male and female fish, however, oocysts were only found in the testes of males. He postulated that after fertilization, a reduction division occurred involving the entire zygote resulting in two migratory ookinetes which carried the infection to the testes. Two separate species may be involved.

Eimeria catostomi Molnar and Hanek, 1974 (Fig. 4a, b)

Hosts: *Catostomus commersoni* "white sucker," *Hypentelium nigricans* "northern hog sucker" (Cypriniformes) (F).

Description: Oocysts spherical, 7.0 (6.5-7.5). Wall smooth, colorless, composed of a single layer ≈ 0.1. Micropyle and oocyst residuum absent. Polar granule present, centrally located, 0.8 (0.7-0.9). Sporocysts ovoid, flattened on one side, 5.5 by 3.8 (5.2-5.9 by 3.6-4.0), in contact with oocyst wall. Sporocysts arranged so that three lie in one plane with fourth overlying. Wall single layered, ≈ 0.2; Stieda body absent. Sporocyst residuum spherical, finely granular, 2.3 (2.0-2.6). Sporozoites vermiform, slightly curved with one end reflected, 4.6 by 1.4 (4.4-4.8 by 1.3-1.6) and lie head to tail within the sporocyst. Refractile bodies absent.

Sporulation: Endogenous.

Geographical location: Ontario, Canada.

Location in host: Anterior intestinal epithelium; feces.

Reference: Molnar and Hanek (1974).

Eimeria duszynskii Conder, Oberndorfer, and Heckmann, 1980 (Fig. 5)

Host: *Cottus bairdi* "mottled sculpin" (Perciformes) (F).

Description: Oocysts irregular in shape, 12.2 (11.6-12.9). Wall very thin, adhering closely to sporocysts. Micropyle, polar granule, and oocyst residuum absent. Sporocysts ovoid, 9.1 by 6.0 (8.4-10.0 by 5.2-6.3), with one side slightly flattened. Stieda and substieda bodies absent. Sporocyst residuum present, compact and coarsely granular, occasionally dispersed. Sporozoites 2.1 wide, lying head to tail in sporocyst with one end reflexed. Each sporozoite contains a large, oblong, refractile body near one end. A spherical nucleus and transverse banding occur at the end opposite from the refractile body.

Sporulation: Endogenous.

Geographical location: Provo river, Utah, U.S.A.

Location in host: Intestinal epithelium; feces.

Reference: Conder et al. (1980).

Eimeria etheostomae Molnar and Hanek, 1974 (Fig. 6)

Hosts: *Etheostoma exile* "Iowa darter," *E. nigrum* "Johnny darter" (Perciformes) (F).

Description: Oocysts spherical, 9.4 (9.1-10.4). Wall smooth and colorless, composed of a single layer ≈ 0.1. Micropyle, polar granule, and oocyst residuum absent. Sporocysts coffee-bean shaped, 8.5 by 5.0 (7.8-9.1 by 4.5-5.4), in contact with oocyst wall. Sporocysts usually arranged so that three lie in one plane with fourth overlying. Stieda body absent. Sporocyst residuum present, spherical, and finely granular, 3.6 (3.1-3.9). Sporozoites banana-shaped, 8.4 by 1.6 (7.8-9.0 by 1.4-1.8), arranged head to tail in sporocyst. Rarely, one end of the sporozoite may be reflexed. Each sporozoite has a spherical refractile body.

Sporulation: About one-half of the oocysts sporulate endogenously; the rest exit semisporulated.

Geographical location: Ontario, Canada.

Location in host: Anterior intestinal epithelium; feces.

Reference: Molnar and Hanek (1974).

Eimeria fernandoae Molnar and Hanek, 1974 (Fig. 7)

Hosts: *Catostomus commersoni* "white sucker," *Hypentelium nigricans* "northern hog sucker" (Cypriniformes) (F).

Description: Oocysts ellipsoid, 8.3 by 6.6 (7.8-9.0 by 6.5-7.0). Wall smooth and colorless, composed of a single layer ≈ 0.1. Micropyle, polar granule, and oocyst residuum absent. Sporocysts ellipsoid, 7.2 by 3.0 (6.8-7.5 by 2.6-3.4), in contact with oocyst wall. All four sporocysts lie parallel in oocyst. Wall 0.2; Stieda body absent. Sporocyst residuum spherical and finely granular, 2.6 (2.3-3.2). Sporozoites banana-shaped, 5.8 by 1.2 (5.2-6.5 by 1.0-1.3), arranged head to tail in sporocyst. Each sporozoite has a spherical refractile body.

Sporulation: Endogenous.

Geographical location: Ontario, Canada

Location in host: Anterior intestinal epithelium; feces.

Reference: Molnar and Hanek (1974).

Eimeria freemani Molnar and Fernando, 1974 (Fig. 8)

Host: *Notropis cornutus* "common shiner" (Cypriniformes) (F).

Description: Oocysts ellipsoid, 22.0-24.0 by 17.0-18.0. Wall smooth and colorless, composed of a single layer ≈ 0.1. Oocyst residuum absent, a micropyle is not described. Polar granule present, 1.0-2.0. Sporocysts ellipsoid, 16.0-17.0 by 5.0-6.5, arranged parallel within oocyst. Wall ≈ 0.2; a Stieda body is not described. Sporocyst residuum spherical, compact, and finely granular, 2.5-5.0. Sporozoites banana-shaped, 14.0-15.5 by 2.5-3.5. Each sporozoite has a large, posterior, refractile body and a smaller refractile body more centrally located.

Sporulation: Endogenous.

Geographical location: Ontario, Canada.

Location in host: Kidney, renal parenchyma, renal tubules.

Reference: Molnar and Fernando (1974).

Eimeria funduli Duszynski, Solangi, and Overstreet, 1979 (Fig. 9)

Hosts: *Fundulus grandis* "gulf killifish," *F. heteroclitus* "mummichog," *F. pulvereus* "bayou killifish," *F. similis* "longnose killifish," *Menidia beryllina* "inland silverside" (Atheriniformes) (B).

Description: Oocysts spherical, 24.5 (20.0-31.0). Wall smooth and colorless, ≈ 1.0, composed of two layers of equal thickness. Outer layer transparent; inner layer opaque. Micropyle, polar granule, and oocyst residuum absent. Sporocysts ovoid, 10.0 by 6.0 (9.0-11.0 by 5.0-7.0). Shape index 1.68 (1.45-2.02). Stieda and substieda bodies present. Thin membrane encloses sporocysts completely forming a transparent matrix, 1.7 (1.0-3.0) wide. Membrane supported by 15 (10-25) footlike structures termed sporopodia attached to outer surface of sporocysts. Sporocyst residuum present, consisting of 1 to 4 refractile granules between the sporozoites. Each sporozoite contains a single refractile body near the posterior end.

Sporulation: Endogenous.

Geographical locations: Estuaries of Mississippi, Alabama, and Louisiana, U.S.A.

Location in host: Liver (rarely intestinal mucosa and submucosa, ovary, testes, caudal peduncle).

References: Duszynski et al. (1979); life-cycle, Solangi and Overstreet (1980), Upton and Duszynski (1982), Fournie and Overstreet (1983); Hawkins, Fournie, and Overstreet (1983b); effect of temperature, Solangi et al. (1982); prevalence, Fournie and Solangi (1980); effects on fish, Solangi and Ogle (1981), Hawkins et al. (1981); transmission studies, Fournie and Overstreet (1982); ultrastructure of sexual stages, Hawkins, Solangi, and Overstreet (1983a, b); ultrastructure of oocysts, Hawkins, Fournie, and Overstreet (1983a).

Eimeria gasterostei (Thélohan, 1890) Doflein, 1909 (Fig. 10)

Synonym: *Coccidium gasterostei* Thélohan, 1890

Hosts: *Gasterosteus aculeatus* "threespine stickleback" (Gasterosteiformes) (F,M).

Description: Oocysts spherical, 16.0-18.0, with smooth thin wall. Oocyst wall greatly separated from sporocysts. Oocyst residuum absent; micropyle and polar granule not described. Sporocysts elongate, narowing at poles, 10.0-14.3 by 4.0-6.5. Sporocyst residuum large and coarsely granular. Sporozoites botuliform, each with a large refractile body.

Sporulation: Endogenous.

Geographical locations: Vancouver, British Columbia; Kamchatka, Paratunka river basin.

Location in host: Liver.

References: Thélohan (1890); Schulman and Shtein (1962); Lester (1974).

Remarks: Description is based on that given by Thélohan (1890), Schulman and Shtein (1962), and Lester (1974).

Eimeria glenorensis Molnar and Fernando, 1974 (Fig. 11)

Host: *Morone americana* "white perch" (Perciformes) (F).

Description: Oocysts spherical, 10.5-12.0. Wall smooth and colorless, composed of a single layer ≈ 0.1. Oocyst residuum absent; a micropyle is not described. One or two polar granules present, 1.0-2.0. Sporocysts ovoid, 8.0-9.5 by 5.7-6.0, in contact with oocyst wall. Stieda body present, consisting of a thickening of the sporocyst wall at tapered end, ≈ 0.5 high; rest of wall ≈ 0.3. Sporocyst residuum spherical and compact, refractile, 2.0-2.6. Sporozoites vermiform, one end reflexed, 5.0-5.3 by 2.0-2.2 (without reflexed portion). Reflexed portion 2.5-2.7 long. Sporozoites arranged head to tail in sporocyst. Refractile bodies absent.

Sporulation: Endogenous.

Geographical location: Ontario, Canada.

Location in host: Intestinal epithelium; feces.

Reference: Molnar and Fernando (1974).

Eimeria haneki Molnar and Fernando, 1974 (Fig. 12)

Host: *Culaea inconstans* "brook stickleback" (Gasterosteiformes) (F).

Description: Oocysts spherical, 7.1-7.8. Wall smooth and colorless, composed of a single layer ≈ 0.1. Oocyst residuum absent; a micropyle is not described. One or two polar granules present, 1.0-1.5. Sporocysts ellipsoid, 5.6-6.5 by 3.9-4.5, compact, and in contact with oocyst wall. Sporocysts usually arranged so that pairs of parallel sporocysts cross each other. Wall ≈ 0.2. A Stieda body is not described. Sporocyst residuum spherical and compact, nongranular, refractile, 1.3-1.5. Sporozoites vermiform, one end reflexed, 5.6-6.0 by 1.3-2.0 (without reflexed portion), arranged head to tail in sporocyst. Each sporozoite has a spherical refractile body.

Sporulation: Endogenous.

Geographical location: Ontario, Canada.

Location in host: Intestinal epithelium; feces.

Reference: Molnar and Fernando (1974).

Eimeria hoffmani Molnar and Hanek, 1974 (Fig. 13)

Host: *Umbra limi* "central mudminnow" (Salmoniformes) (F).

Description: Oocysts ellipsoid, 11.5 by 9.2 (11.0-12.2 by 9.1-9.6). Wall smooth and colorless, composed of a single layer ≈ 0.1. Micropyle and oocyst residuum absent. Polar granule present, 0.8 (0.7-0.9). Sporocysts ellipsoid, 10.0 by 3.6 (9.6-10.4 by 3.4-3.9), arranged lengthwise and parallel in oocyst. Wall ≈ 0.2; Stieda body absent. Sporocyst residuum ellipsoid and finely granular, 6.4 by 2.0 (6.2-6.6 by 1.8-2.2). In older oocysts the residuum is either less elongate or dispersed. Sporozoites vermiform, one end reflexed, 8.6 by 1.4 (8.4-8.7 by 1.3-1.5), (without reflexed portion), arranged head to tail in sporocyst. Refractile bodies absent.

Sporulation: Endogenous.

Geographical location: Ontario, Canada.

Location in host: Anterior intestinal epithelium; feces.

Reference: Molnar and Hanek (1974).

Eimeria hybognathi Molnar and Fernando, 1974 (Fig. 14)

Host: *Hybognathus hankinsoni* "brassy minnow" (Cypriniformes) (F).

Description: Oocysts spherical, 14.0-14.5. Wall of uniform thickness, composed of a single layer ≈ 0.1. Polar granule and oocyst residuum absent. A micropyle is not described. Sporocysts ellipsoid, 9.5-10.0 by 5.7-6.0, with a narrow space separating them from oocyst wall. They are usually arranged so that pairs of parallel sporocysts cross each other. Sometimes three lie in one plane with the fourth overlying. Wall ≈ 0.2. A Stieda body is not described. Sporocyst residuum ovoid, compact, and finely granular, 5.8-8.0 by 4.5-5.2. Sporozoites banana-shaped, one end slightly reflected, 9.0-9.2 by 2.0-2.6, lying head to tail in sporocyst. A single spherical refractile body is present in each sporozoite.

Sporulation: Endogenous.

Geographical location: Ontario, Canada.

Location in host: Intestinal epithelium; feces.

Reference: Molnar and Fernando (1974).

Eimeria ictaluri Molnar and Fernando, 1974 (Fig. 15)

Host: *Ictalurus nebulosus* "brown bullhead" (Siluriformes) (F).

Description: Oocysts spherical, 9.0-10.5. Wall colorless and of uniform thickness, composed of a single layer ≈ 0.1. Polar granule and oocyst residuum absent; a micropyle is not described. Sporocysts ellipsoid, rarely coffee-bean shaped, 7.8-8.4 by 3.6-4.2, in contact with oocyst wall. Sporocysts usually arranged so that pairs of parallel sporocysts cross each other. Wall 0.2; a Stieda body is not described. Sporocyst residuum ovoid, compact, and coarsely granular, 5.0-5.3 by 3.0-3.3. Sporozoites vermiform, one end reflexed, 7.1-7.8 by 1.5-1.8, without reflexed portion, arranged head to tail in sporocyst. Each sporozoite has a spherical refractile body.

Sporulation: Endogenous.

Geographical location: Ontario, Canada.

Location in host: Intestinal epithelium; feces.

Reference: Molnar and Fernando (1974).

Eimeria iroquoina Molnar and Fernando, 1974 (Fig. 16)

Hosts: *Nocomis biguttatus* "hornyhead chub," *Notropis cornutus* "common shiner," *N. heterolepis* "blacknose shiner," *N. rubellus* "rosyface shiner," *Pimephales notatus* "bluntnose minnow," *P. promelas* "fathead minnow," *Rhinichthys atratulus* "blacknose dace," *Semotilus atromaculatus* "creek chub" (Cypriniformes) (F).

Description: Oocysts spherical, 9.0-11.0. Wall colorless and of uniform thickness, composed of a single layer ≈ 0.1. Polar granule and oocyst residuum absent; a micropyle is not described. Sporocysts ellipsoid, 7.8-8.0 by 4.0-4.5, in contact with oocyst wall. Sporocysts usually arranged so that pairs of parallel sporocysts cross each other. Wall ≈ 0.2; a Stieda body is not described. Sporocyst residuum ovoid, finely granular, 2.3-4.0 by 2.2-3.0. Sporozoites vermiform, one end reflexed, 7.5-7.7 by 1.5-1.7 (without reflexed portion), arranged head to tail in sporocyst. Each sporozoite has a spherical refractile body.

Sporulation: Endogenous.

Geographical location: Ontario, Canada.

Location in host: Intestinal epithelium; feces.

References: Molnar and Fernando (1974); Molnar and Hanek (1974); Paterson and Desser (1981a, b, c, 1982).

Eimeria laureleus Molnar and Fernando, 1974 (Fig. 17)

Host: *Perca flavescens* "yellow perch" (Perciformes) (F).

Description: Oocysts spherical, 11.0-12.0. Wall colorless and of uniform thickness, composed of a single layer ≈ 0.1. Polar granule and oocyst residuum absent; a micropyle is not described. Sporocysts coffee-bean shaped, 9.2-11.0 by 5.0-5.8, in contact with oocyst wall. Sporocysts usually arranged so that pairs of parallel sporocysts cross each other. A Stieda body is not described. Sporocyst residuum finely granular and dispersed. Sporozoites vermiform, one end reflexed, 9.0-10.0 by 1.5-2.0, without reflexed portion, arranged head to tail in sporocyst. Each sporozoite has a spherical refractile body.

Sporulation: Endogenous.

Geographical location: Ontario, Canada.

Location in host: Intestinal epithelium; feces.

Reference: Molnar and Fernando (1974).

Eimeria micropteri Molnar and Hanek, 1974 (Fig. 18)

Host: *Micropterus dolomieui* "smallmouth bass," *M. salmoides* "largemouth bass" (Perciformes) (F).

Description: Oocysts spherical, 12.0 (11.7-12.5). Wall smooth and colorless, composed of a single layer ≈ 0.1. Micropyle, polar granule, and oocyst residuum absent. Sporocysts ellipsoid, 11.4 by 6.2 (11.0-11.7 by 6.0-6.5), in contact with oocyst wall. Sporocysts arranged three in one plane with fourth overlying. Wall ≈ 0.2; Stieda body absent. Sporocyst residuum finely granular, dispersed. Sporozoites vermiform, one end reflexed, 9.1 by 2.1 (8.9-9.3 by 2.0-2.2), (without reflexed portion), arranged head to tail in sporocyst. Each sporozoite has a spherical refractile body.

Sporulation: About 90% leave the gut semisporulated; the rest exit fully sporulated.

Geographical location: Ontario, Canada.

Location in host: Anterior intestinal epithelium; feces.

Reference: Molnar and Hanek (1974).

Eimeria moronei Molnar and Fernando, 1974 (Fig. 19)

Host: *Morone americana* "white perch" (Perciformes) (F).

Description: Oocysts spherical, 7.2-8.0. Wall colorless and of uniform thickness, composed of a single layer ≈ 0.1. Oocyst residuum absent; a micropyle is not described. Polar granule present, 1.0-2.0. Sporocysts ovoid, 5.7-6.0 by 3.9-4.0, in contact with oocyst wall. Sporocysts arranged three in one plane with fourth overlying. Wall ≈ 0.2; Stieda body present, consisting of a distinct knoblike thickening at tapered end. Sporocyst residuum spherical, compact, refractile, 1.5-2.0. Sporozoites vermiform, 5.0-5.4 by 1.5-2.0, arranged head to tail in sporocyst. Refractile bodies absent.

Sporulation: Endogenous.

Geographical location: Ontario, Canada.

Location in host: Intestinal epithelium; feces.

Reference: Molnar and Fernando (1974).

Eimeria myoxocephali Fitzgerald, 1975 (Fig. 20)

Host: *Myoxocephalus polyacanthocephalus* "great sculpin" (Perciformes) (M).

Description: Oocysts spherical, 37.2 (34.0-40.0). Wall bilayered and smooth, ≈ 2.0. Micropyle and oocyst residuum absent; a polar granule is not described or depicted. Sporocysts composed of a thin membrane stretched tightly around the sporozoites. Sporocyst residuum present, small, and spherical. Sporozoites elongate, 16.7 by 3.7, twisted around each other and arranged head to tail in sporocyst membrane. A single refractile body is present in each sporozoite.

Sporulation: Endogenous.

Geographical location: Puget Sound, Washington, U.S.A.

Location in host: Anterior intestinal mucosa; feces.

Reference: Fitzgerald (1975).

Eimeria ojibwana Molnar and Fernando, 1974 (Fig. 21)

Host: *Cottus bairdi* "mottled sculpin" (Perciformes) (F).

Description: Oocysts spherical, 10.4-11.0. Wall colorless and of uniform thickness, composed of a single layer ≈ 0.1. Polar granule and oocyst residuum absent; a micropyle is not described. Sporocysts coffee-bean shaped, 9.0-9.2 by 5.0-5.8, in contact with oocyst wall. Sporocysts usually arranged so that pairs of parallel sporocysts cross each other. Wall ≈ 0.2; a Stieda body is not described. Sporocyst residuum composed of irregularly sized granules, dispersed. Sporozoites vermiform, reflexed on one end, 8.4-8.7 by 2.0-2.5 (without reflexed portion), arranged head to tail in sporocyst. Each sporozoite has a spherical refractile body.

Sporulation: Endogenous.

Geographical location: Ontario, Canada.

Location in host: Intestinal epithelium; feces.

Reference: Molnar and Fernando (1974).

Eimeria osmeri Molnar and Fernando, 1974 (Fig. 22)

Host: *Osmerus mordax* "rainbow smelt" (Salmoniformes) (F).

Description: Oocysts spherical, 10.4-11.0. Wall colorless and of uniform thickness, composed of a single layer ≈ 0.1. Oocyst residuum absent; a micropyle is not described. One or two polar granules present, 1.5-1.7. Sporocysts ovoid, 7.1-7.8 by 4.3-4.7, with a narrow space separating them from oocyst wall. Stieda body present, consisting of thickening of sporocyst wall at tapered end, ≈ 0.4 high; rest of sporocyst wall ≈ 0.2. Sporocyst residuum spherical and compact, refractile, 1.3-1.7. Sporozoites vermiform, reflexed on one end, 6.0-7.1 by 1.3-1.7 (without reflexed portion), arranged head to tail in sporocyst. Refractile bodies absent.

Sporulation: Endogenous.

Geographical location: Ontario, Canada.

Location in host: Intestinal epithelium; feces.

Reference: Molnar and Fernando, 1974.

Eimeria pungitii Molnar and Hanek, 1974 (Fig. 23)

Host: *Pungitius pungitius* "ninespine stickleback" (Gasterosteiformes) (F).

Description: Oocysts ellipsoid, 12.5 by 9.8 (12.1-13.0 by 8.6-10.4). Wall smooth and colorless, composed of a single layer ≈ 0.1. Micropyle, polar granule, and oocyst residuum absent. Sporocysts ellipsoid, 10.0 by 3.6 (9.1-10.4 by 3.4-3.9), in contact with oocyst wall. All four sporocysts arranged lengthwise and parallel in oocyst. Wall ≈ 0.2; Steida body absent. Sporocyst residuum granular, dispersed, completely filling sporocyst. Sporozoites banana-shaped, 8.7 by 2.3 (8.4-9.1 by 2.1-2.4), arranged head to tail in sporocyst. Each sporozoite contains a spherical refractile body.

Sporulation: Most oocysts leave the host unsporulated.

Geographical location: Quebec, Canada.

Location in host: Anterior intestinal epithelium; feces.

Reference: Molnar and Hanek (1974).

Eimeria salvelini Molnar and Hanek, 1974 (Fig. 24)

Host: *Salvelinus fontinalis* "brook trout" (Salmoniformes) (F).

Description: Oocysts spherical, 12.0 (11.7-12.5). Wall smooth and colorless, composed of a single layer ≈ 0.1. Micropyle, polar granule, and oocyst residuum absent. Sporocysts ovoid, 9.2 by 5.1 (9.0-9.4 by 5.0-5.3), in contact with oocyst wall. Caplike Stieda body present at tapered end, 1.1 (0.9-1.3) high; rest of wall ≈ 0.2. Sporocysts arranged three in one plane with fourth overlaying. Sporocyst residuum spherical and compact, 1.8 (1.5-2.1). Sporozoites vermiform, 6.8 by 1.5 (6.5-7.1 by 1.3-1.7), characteristically interlaced. Refractile bodies absent.

Sporulation: Endogenous.

Geographical location: Quebec, Canada.

Location in host: Anterior intestinal epithelium; feces.

Reference: Molnar and Hanek (1974).

Eimeria squali Fitzgerald, 1975 (Fig. 25)

Host: *Squalus acanthias* "spiny dogfish shark" (Chondrichthyes) (M).

Description: Oocysts ovoid or ellipsoid, 24.0-36.0 by 20.0-29.0. Wall brownish lavender, pitted, with the bottoms of the pits light green or grey. Sporont spherical, 19.9 (16.0-28.0). Micropyle absent; a polar granule is not described. Oocyst residuum ≈ 12.4. Sporocysts ellipsoid, 19.6 by 5.9. Several fibers extend from pointed ends of sporocysts when forced from oocysts, disappearing shortly after leaving oocyst. A Stieda body is not described. Sporocyst residuum consisting of several small, spherical granules in each sporocyst. Sporozoites slender, spindle-shaped, 13.6 by 2.2, slightly twisted in a head to tail arrangement. Each sporozoite has weakly visible cross striations while still in the sporocyst extending for about one-fifth of its length at the larger end. Refractile body not described but depicted at end opposite to striations in sporozoite.

Sporulation: Exogenous.

Geographical location: Puget Sound, Washington, U.S.A.

Location in host: Mucosa of spiral valve; feces.

Reference: Fitzgerald (1975).

Eimeria tedlai Molnar and Fernando, 1974 (Fig. 26)

Host: *Perca flavescens* "yellow perch" (Perciformes) (F).

Description: Oocysts spherical, 9.5-10.0. Wall colorless and of uniform thickness, consisting of a single layer ≈ 0.1. Oocyst residuum absent; a micropyle is not described. Polar granule present, refractile, 1.0-1.5. Sporocysts ovoid, 8.4-8.7 by 4.5-4.7, in contact with oocyst wall. Sporocysts usually arranged so that pairs of parallel sporocysts cross each other. Caplike Stieda body at tapered end, 1.5-2.0 high; rest of wall ≈ 0.3. Sporocyst residuum spherical or ellipsoid, refractile, 1.5-2.6 by 1.5-2.0. Sporozoites vermiform, one end reflexed, 6.0-6.5 by 1.6-2.1 (without reflexed portion), arranged head to tail in sporocyst. Refractile bodies absent.

Sporulation: Endogenous.

Geographical location: Ontario, Canada.

Location in host: Intestinal epithelium; feces.

Reference: Molnar and Fernando (1974).

Eimeria truttae (Léger and Hesse, 1919) Stankovitch, 1924 (Fig. 27)

Synonym: *Goussia truttae* Léger and Hesse, 1919.

Hosts: *Salvelinus fontinalis* "brook trout," *Salmo trutta fario* "German brown trout" (Salmoniformes) (F).

Description: Oocysts spherical, 12.8 (12.3-13.0). Wall smooth and colorless, composed of a single layer ≈ 0.1. Micropyle and oocyst residuum absent. Polar granule present, 0.9 (0.7-1.0). Sporocysts ovoid, 10.1 by 6.0 (9.3-11.0 by 5.0-6.5), in contact with oocyst wall. Sporocysts arranged parallel in oocyst. Disclike Stieda body present at tapered end of sporocyst, 2.7 (2.6-2.8). Sporocyst residuum spherical and finely granular, 2.8 (2.6-3.0). Sporozoites vermiform, one end reflexed, 8.5 by 1.6 (7.8-9.0 by 1.3-2.0), (without reflexed portion), arranged head to tail in sporocyst. Refractile bodies absent.

Sporulation: Endogenous.

Geographical locations: Quebec, Canada; France.

Location in host: Anterior intestinal epithelium; feces.

References: Léger and Hesse (1919); Molnar and Hanek (1974).

Remarks: Description is based predominately on that of Molnar and Hanek (1974).

In addition to those species listed previously, a number of incidental findings of *Eimeria* from North American fishes occur in the literature. Listed below are those which we have located. Others undoubtedly exist.

Eimeria sp. Davis, 1946

Host: *Salvelinus fontinalis* "brook trout" (Salmoniformes) (F).

Description: None given.

Sporulation: Endogenous.

Geographical location: Rutland, Vermont, U.S.A.

Location in host: Intestinal epithelium of pyloric caeca; feces.

Reference: Davis (1946).

Remarks: Various developmental stages of an eimerian were found in the epithelium of the pyloric caeca and, to a lesser extent, in the epithelium proximal to the caeca. This species may be *E. salvelini* or *E. truttae*, which occur in *S. fontinalis* in Ontario, Canada.

Eimeria sp. Fantham and Porter, 1948

Host: *Fundulus heteroclitus* "mummichog" (Atheriniformes) (B).

Description: None given.

Sporulation: Endogenous (?).

Geographical location: Halifax, Nova Scotia.

Location in host: Unknown.

Reference: Fantham and Porter (1948).

Remarks: This species may be *E. funduli* (Duszynski et al. 1979).

Eimeria sp. Fantham and Porter, 1948

Host: *Salvelinus fontinalis* "brook trout" (Salmoniformes) (F).

Description: None given.

Sporulation: Endogenous.

Geographical location: Quebec, Canada.

Location in host: Intestine.

Reference: Fantham and Porter (1948).

Remarks: This species may be *E. salvelini* or *E. truttae*, which occur in *S. fontinalis* in Ontario, Canada.

Eimeria sp. Munson, 1974

Host: *Liparis atlanticus* "seasnail" (Perciformes) (M).

Description: None given.

Sporulation: Endogenous (?).

Geographical location: New Hampshire, U.S.A.

Location in host: Intestinal epithelium; heaviest infections in posterior intestine.

Reference: Munson (1974).

Remarks: This species was found in 128/128 (100%) of all fish examined and caused serious histopathological damage. It probably represents an undescribed new species.

Eimeria sp. Orias and Noble, 1971

Host: *Nezumia bairdi* "marlin-spike" or "common grenadier" (Gadiformes) (M).

Description: Sporocysts averaged 9.5 by 5.5.

Sporulation: Endogenous.

Geographical location: Off coast of Greenland.

Location in host: Stomach epithelium.

Reference: Orias and Noble (1971).

Remarks: This eimerian probably represents an undescribed new species.

Genus *Goussia* Labbé, 1896

Oocysts contain four sporocysts, each with two sporozoites; Stieda body absent; sporocyst wall bivalved.

Goussia caseosa Lom and Dyková, 1982 (Fig. 28, sporocyst only)

Host: *Macrourus berglax* "roughhead grenadier" (Gadiformes) (M).

Description: Oocysts irregular in shape, 42.0 (40.0-47.0). Wall thin, membranelike, easily ruptured, and coated with fine granules. Micropyle and polar granule not mentioned or depicted. Oocyst residuum absent. Sporocysts ellipsoid, 19.2 by 13.6 (18.0-20.3 by 12.0-15.5), with thick sporocyst wall. Sporocyst residuum absent. Sporozoites 26.0 by 7.0, arranged head to tail in sporocyst and partially curled around one another. Anterior ends of sporozoites with transverse striations, disappearing when sporozoites excyst. Sporozoite refractile bodies not mentioned but clearly depicted.

Sporulation: Endogenous.

Geographical location: Grand Banks, Newfoundland.

Location in host: Swim bladder, gas gland, gall bladder, intestinal contents, mesenteric blood vessels.

Reference: Lom and Dyková (1982a).

Goussia degiustii (Molnar and Fernando, 1974) Dyková and Lom, 1981 (Fig. 29)

Synonyms: *Eimeria spleni* DeGiusti and Hnath, 1968; *Eimeria degiusti* Molnar and Fernando, 1974.

Hosts: *Notropis cornutus* "common shiner," *Pimephales notatus* "bluntnose minnow," *P. promelas* "fathead minnow," *Campostoma anomalum* "central stoneroller" (Cypriniformes) (F).

Description: Oocysts spherical, 19.0-22.0. Wall colorless and of uniform thickness, consisting of a single layer ≈ 0.1. Oocyst residuum absent; a micropyle is not described. One or two polar granules present, 1.0-2.0. Sporocysts ellipsoid, 13.0-14.5 by 6.5-8.5, with a relatively narrow space separating them from oocyst wall. Wall ≈ 0.2. A thin membranous collar, apparently visible only with electron microscopy, girdles the sporocyst at the suture. Sporocyst residuum compact and coarsely granular, 9.0-10.0 by 7.0-8.0. Sporozoites banana-shaped, 10.5-12.0 by 2.5-2.8, arranged head to tail in sporocyst. A spherical refractile body is present in each sporozoite.

Sporulation: Endogenous.

Geographical location: Ontario, Canada.

Location in host: Spleen.

References: DeGiusti and Hnath (1968); Lom (1971); Molnar and Fernando (1974); Dyková and Lom (1981); Paterson and Desser (1982).

Remarks: *Eimeria spleni* was mentioned, but not described, by DeGiusti and Hnath (1968) and later examined ultrastructurally by Lom (1971). However, Molnar and Fernando (1974) described the morphology of the species and, thus, *E. spleni* is a nomen nudum.

Goussia gadi (Fiebiger, 1913) Dyková and Lom, 1981 (Fig. 30)

Synonym: *Eimeria gadi* Fiebiger, 1913.

Hosts: *Gadus* (=*Melanogrammus*) *aeglefinus* "haddock," *G. morrhua* "common cod" or "codfish," *G. virens* "coal-fish," *Enchelyopus cimbrius* "fourbeard rockling," *Molva vulgaris* "ling" (Gadiformes) (M).

Description: Oocysts spherical, 26.0-28.0, with a smooth thin wall. Micropyle and polar granule not described. Oocyst residuum sometimes present. Sporocysts ovoid, 11.0-15.0 by 7.5-10.0, with apical pore and longitudinal ridges extending length of sporocyst (not visible with light microscopy). Sporocyst residuum present. Sporozoites 16.0 by 4.0, and contain one or more refractile bodies.

Sporulation: Endogenous.

Geographical location: North Atlantic Ocean.

Location in host: Swim bladder.

References: Fiebiger (1913); Odense and Logan (1976); Scott (1981); Schulman and Shtein (1962); Dyková and Lom (1981).

Remarks: This description is based on that given by Fiebiger (1913) and Odense and Logan (1976).

KEY TO EIMERIIDAE OF NORTH AMERICAN FISHES

1a. Sporocysts nonbivalved; with or without Stieda body (*Eimeria*) 2
1b. Sporocysts bivalved; without Stieda body (*Goussia*)[4] 28

[4]All tetrasporocystic oocysts which have dizoic sporocysts and lack Stieda bodies may eventually prove to be *Goussia*. The suture is often difficult or impossible to see with light microscopy. However, both Odense and Logan (1976) and Lom and Dyková (1982a) have published photomicrographs which suggest that crushing sporocysts between slide and coverglass can separate the valves at the suture; this making electron microscopy unnecessary for diagnosis.

2a. Stieda body present; oocysts spherical; oocyst residuum absent 3
2b. Stieda body absent; oocysts vary in shape 10
3a. Oocysts > 20 μm with wall ≈ 1.0 μm thick; sporocysts with sporopodia; sporulation endogenous, in liver of Atheriniformes ..... *E. funduli*
3b. Oocysts < 15 μm with wall ≈ 1.0 μm; sporocysts without sporopodia 4
4a. One or more polar granules present 5
4b. Polar granule absent 9
5a. Stieda body disc-shaped; sporulation endogenous, in anterior intestinal epithelium of Salmoniformes ..... *E. truttae*
5b. Stieda body not as above 6
6a. Stieda body caplike at tapered end of sporocyst; sporulation endogenous, in intestinal epithelium of Perciformes ..... *E. tedlai*
6b. Stieda body a knoblike thickening at tapered end of sporocyst 7
7a. Oocyst small, < 10 μm in greatest diameter; sporulation endogenous, in intestinal epithelium of Perciformes ..... *E. moronei*
7b. Oocyst > 10 μm in diameter 8
8a. Sporocysts 8-10 μm long and in contact with oocyst wall; sporulation endogenous, in intestinal epithelium of Perciformes ..... *E. glenorensis*[5]
8b. Sporocysts ≤ 8 μm long leaving space separating them from oocyst wall; sporulation endogenous, in intestinal epithelium of Salmoniformes ..... *E. osmeri*[5]
9a. Stieda body formed by 4 papillae, sporocysts hexagonal in cross-section; sporulation endogenous, in anterior intestinal epithelium of Anguilliformes ..... *E. anguillae*
9b. Stieda body caplike, sporocyst round in cross-section; sporulation endogenous, in anterior intestinal epithelium of Salmoniformes ..... *E. salvelini*
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10b. Oocyst residuum absent 12
11a. Oocyst spheroid to ovoid, outer wall smooth; sporulation endogenous, oocysts in testes of Clupeiformes ..... *E. brevoortiana*
11b. Oocyst ellipsoid to ovoid, outer wall pitted, brown; sporulation exogenous, merogony in spiral valve mucosa of Chondrichthyes ..... *E. squali*
12a. Oocyst spheroid, > 30 μm in diameter, with thick (3 μm) wall; sporulation endogenous, in anterior intestinal mucosa of Scorpaeniformes ..... *E. myoxocephali*
12b. Oocyst spheroid or otherwise, < 30 μm in any dimension, with thin (≈ 0.1 μm) wall 13
13a. One or more polar granules present 14
13b. Polar granule absent 17
14a. Oocyst spheroid, < 10 μm in diameter 15
14b. Oocyst ellipsoid 16
15a. Sporocysts ovoid, flat on one side; sporozoites without refractile body; sporulation endogenous, in anterior intestinal epithelium of Cypriniformes ..... *E. catostomi*
15b. Sporocysts ellipsoid, not flat on one side, sporozoites with refractile body; sporulation endogenous, in intestinal epithelium of Gasterosteiformes ..... *E. haneki*
16a. Oocyst small, greatest length < 20 μm; sporulation endogenous, in anterior intestinal epithelium of Salmoniformes ..... *E. hoffmani*
16b. Oocyst large, smallest length > 20 μm; sporulation endogenous, in kidneys and renal parenchyma of Cypriniformes ..... *E. freemani*
17a. Sporocyst residuum absent; sporulation exogenous, merogony in anterior intestinal epithelium of Cypriniformes ..... *E. aurati*
17b. Sporocyst residuum present 18
18a. Oocyst irregular in shape with wall tightly adhering to sporocysts; sporulation endogenous, in intestinal epithelium of Scorpaeniformes ..... *E. duszynskii*
18b. Oocyst spheroid or ellipsoid 19
19a. Oocyst ellipsoid 20
19b. Oocyst spheroid 21
20a. Oocyst 7.5-9 × 6-7 μm, sporocysts 6-8 × 2-3.5 μm; sporulation endogenous, in anterior intestinal epithelium of Cypriniformes ..... *E. fernandoae*
20b. Oocyst 12-13 × 8-10.5 μm, sporocysts 9-10.5 × 3-4 μm; sporulation mostly exogenous; merogony in anterior intestinal epithelium of Gasterosteiformes ..... *E. pungitii*
21a. Oocyst smallest diameter > 15 μm, sporulation endogenous in liver of Gasterosteiformes ..... *E. gasterostei*
21b. Oocyst largest diameter ≤ 15 μm; sporocysts elongate; sporulation endogenous in gut epithelium 22
22a. Sporocysts appear triangular in cross section, with granular residuum 23
22b. Sporocysts not triangular in cross section 25
23a. Sporocyst residuum dispersed 24
23b. Sporocyst residuum compact, coarsely granular; ellipsoid sporocysts always < 9.0 μm long; sporulation endogenous in intestinal epithelium of Siluriformes ..... *E. ictaluri*[6]

[5]Oocysts of these "species" are nearly identical and, in fact, may represent the same species. In their original description, Molnar and Fernando (1974) argued, "It is well known that *Eimeria* spp. are highly specific to single or closely related host species" and "... when morphologically almost indistinguishable or very similar *Eimeria* spp. occur in distantly related host species, we consider these parasites as distinct species...." This assumption may prove invalid with time, but our knowledge of the life cycles of fish eimerians is too incomplete to refute it at this time.

[6]Oocysts of these "species" are nearly identical and may represent a single species. See footnote 5.

24a. Sporocyst residuum finely granular, sporocysts always > 9.0 μm long; sporulation endogenous in intestinal epithelium of Perciformes ..... *E. laureleus*[6]
24b. Sporocyst residuum granules of various sizes; sporulation endogenous, in intestinal epithelium of Scorpaeniformes ..... *E. ojibwana*[6]
25a. Both oocyst diameter and sporocyst smallest length > 11.0 μm; sporulation mostly exogenous, merogony and some sporulation in anterior intestinal epithelium of Perciformes ..... *E. micropteri*[6]
25b. Oocyst diameter and sporocyst length not as above 26
26a. Oocyst diameter always > 14.0 μm; sporocyst length always ≤ 10.0 μm; sporulation endogenous in intestinal epithelium of Cypriniformes ..... *E. hybognathi*[6]
26b. Oocyst and sporocyst measurements not as above 27
27a. Sporozoite longer than sporocyst with one end reflexed back upon itself; sporulation endogenous, in intestinal epithelium of Cypriniformes ..... *E. iroquoina*[6]
27b. Sporozoites slightly shorter than length of sporocyst, rarely reflexed; sporulation endogenous and exogenous; merogony in anterior intestinal epithelium of Cypriniformes ..... *E. etheostomae*
28a. Oocysts irregular in shape, with thin, membranelike wall; sporulation endogenous in numerous tissues of Gadiformes .... *G. caseosa*
28b. Oocysts spherical 29
29a. One or more polar granules present; sporulation endogenous, in spleen of Cypriniformes ..... *G. degiustii*
29b. Polar granule absent; sporulation endogenous, in swim bladder of Gadiformes ..... *G. gadi*

ACKNOWLEDGMENTS

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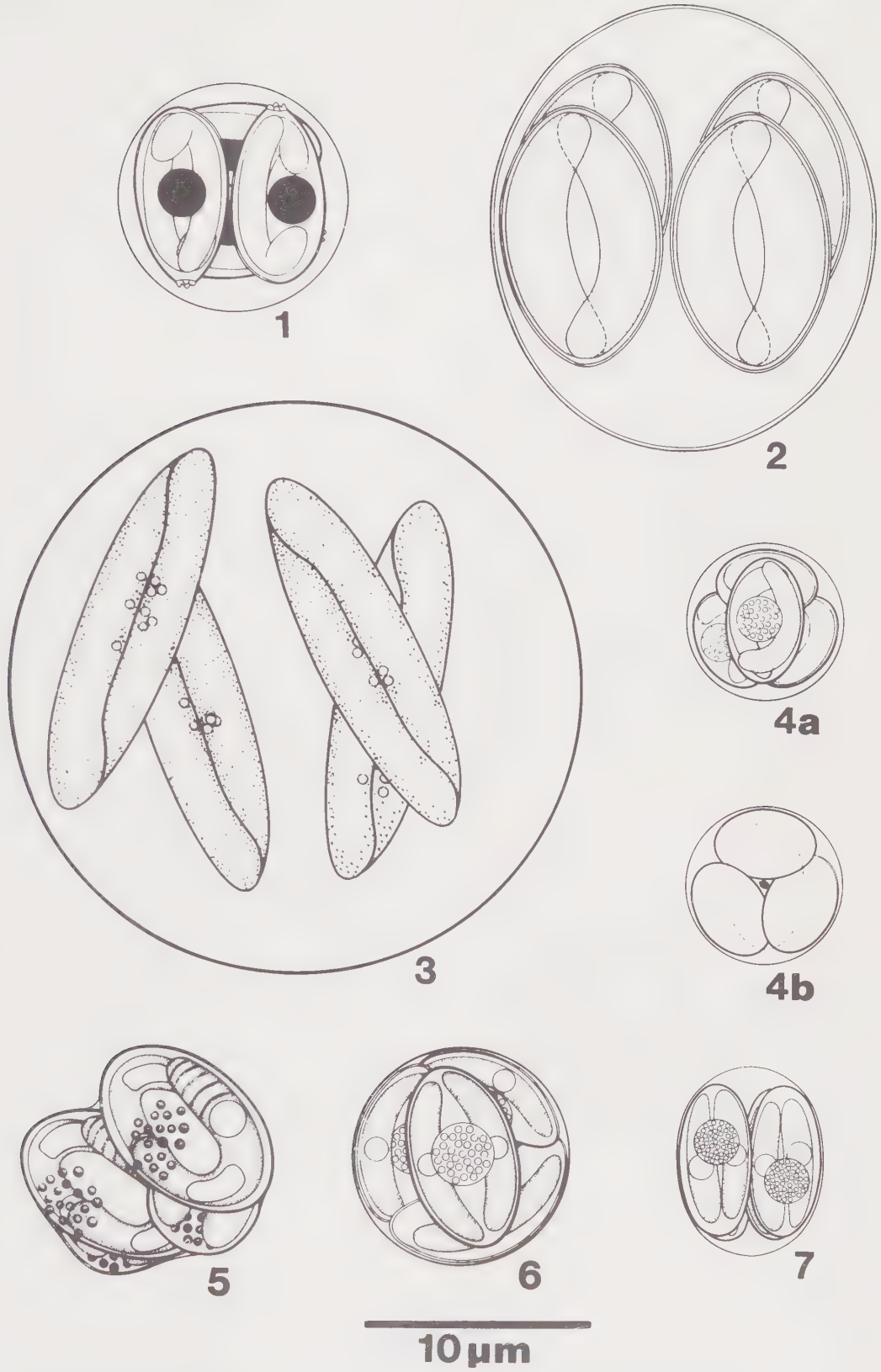
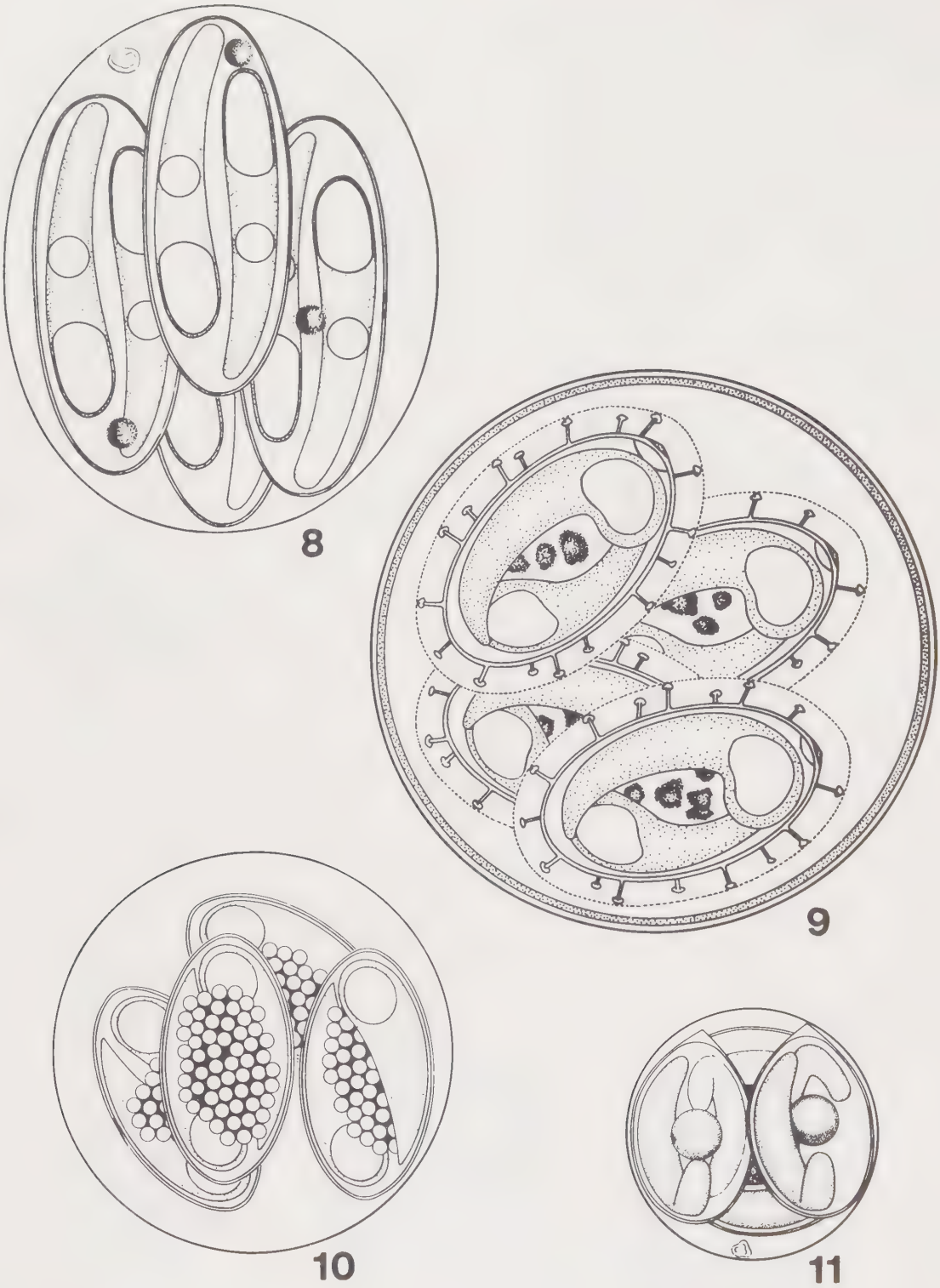
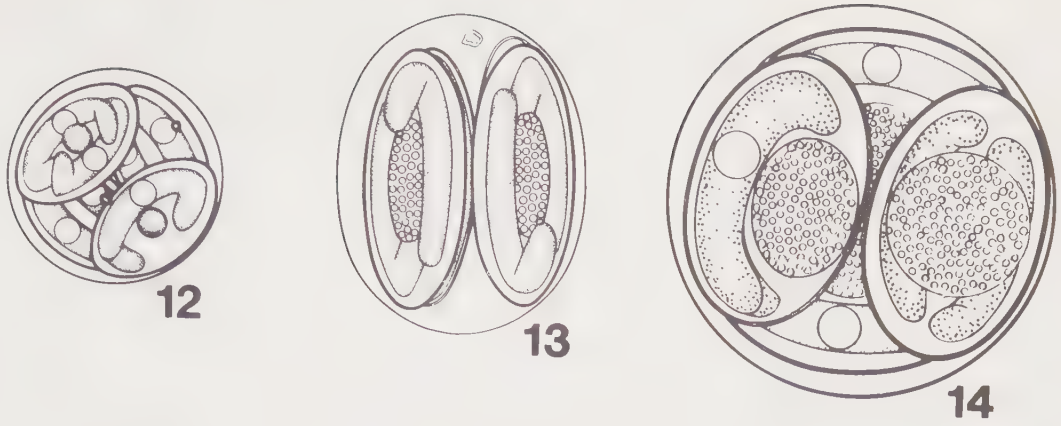
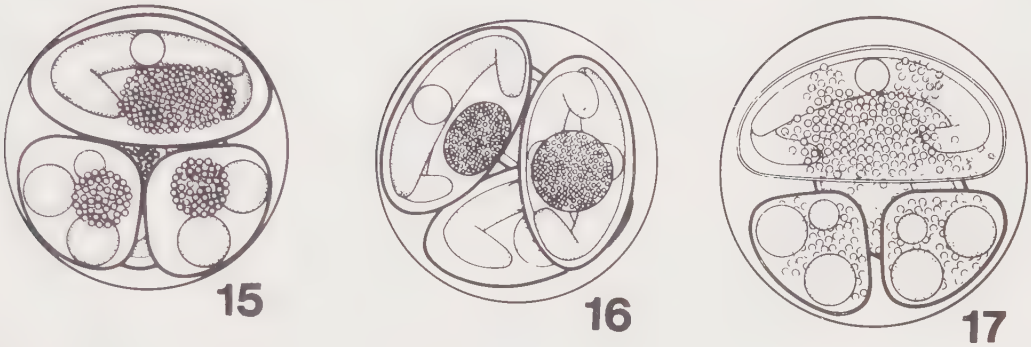


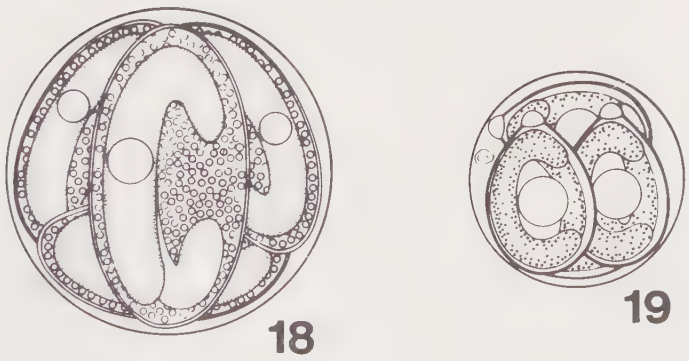
Figures 1-30.—Composite line drawings of oocysts and/or sporocysts of Eimeriidae of North American fish. Minor discrepancies may exist between drawings and text. All figures redrawn from previously published drawings or photomicrographs. 1. *Eimeria anguillae* (from Molnar and Hanek 1974); 2. *E. aurati* (from Hoffman 1965); 3. *E. brevoortiana* (from Hardcastle 1944); 4. *E. catostomi* (from Molnar and Hanek 1974) (a) oocyst, entire view (b) section through oocyst showing position of polar granule; 5. *E. duszynskii* (from Conder et al. 1980); 6. *E. etheostomae* (from Molnar and Hanek 1974); 7. *E. fernandoae* (from Molnar and Hanek 1974); 8. *E. freemani*



(from Molnar and Fernando 1974); 9. *E. funduli* (from Duszynski et al. 1979; pers. obs.); 10. *E. gasterostei* (from Schulman and Shtein 1962); 11. *E. glenorensis* (from Molnar and Fernando 1974); 12. *E. haneki* (from Molnar and Fernando 1974); 13. *E. hoffmani* (from Molnar and Hanek 1974); 14. *E. hybognathi* (from Molnar and Fer-

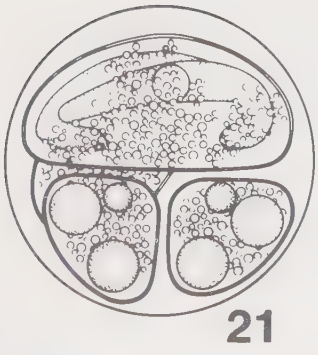


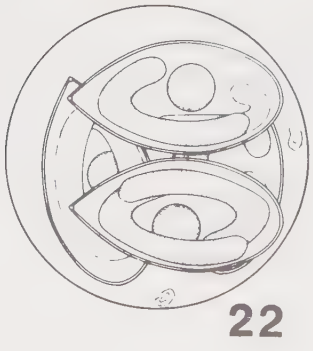


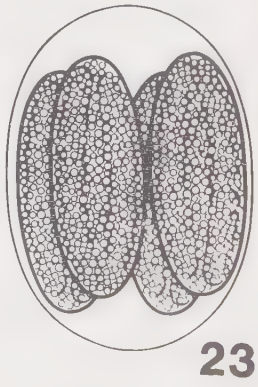


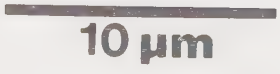
10µm

nando 1974); 15. *E. ictaluri* (from Molnar and Fernando 1974); 16. *E. iroquoina* (from Molnar and Fernando 1974); 17. *E. laureleus* (from Molnar and Fernando 1974); 18. *E. micropteri* (from Molnar and Fernando 1974); 19. *E. moronei* (from Molnar & Fernando 1974); 20. *E. myoxocephali* (from Fitzgerald 1975); 21. *E. ojibwana* (from

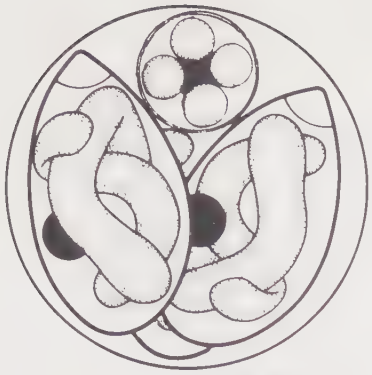








Molnar and Hanek 1974); 22. *E. osmeri* (from Molnar and Fernando 1974); 23. *E. pungitii* (from Molnar and Hanek 1974); 24. *E. salvelini* (from Molnar and Hanek



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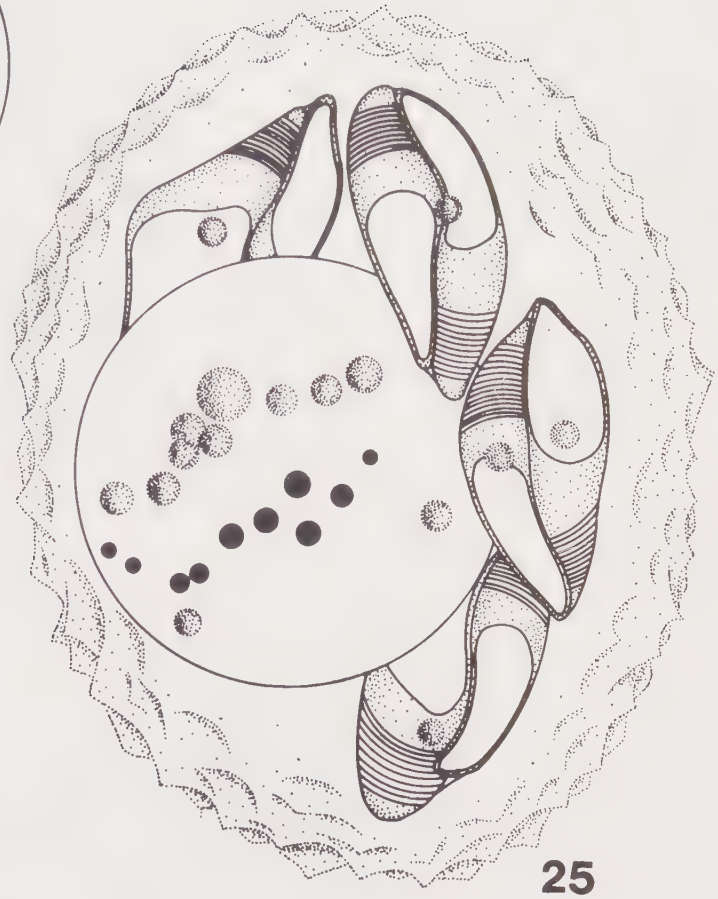

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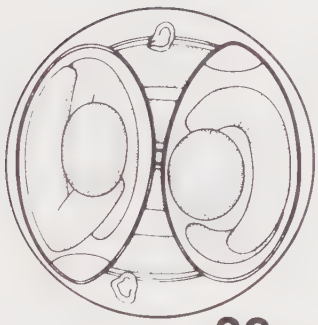

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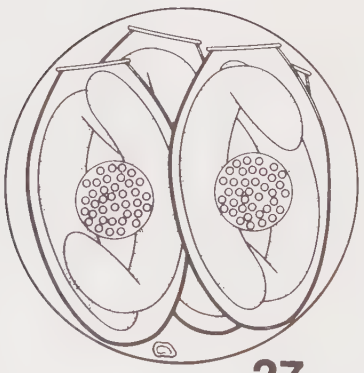
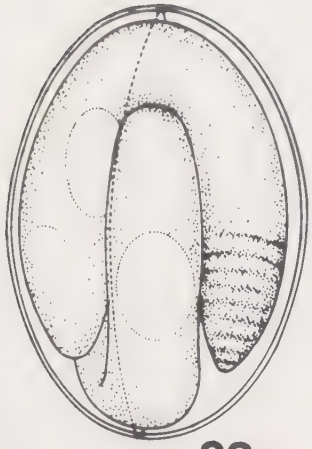


27

10 µm

1974); 25. *E. squali* (from Fitzgerald 1975); 26. *E. tedlai* (from Molnar and Fernando 1974); 27. *E. truttae* (from Molnar and Hanek 1974); 28. Sporocyst of *Goussia*



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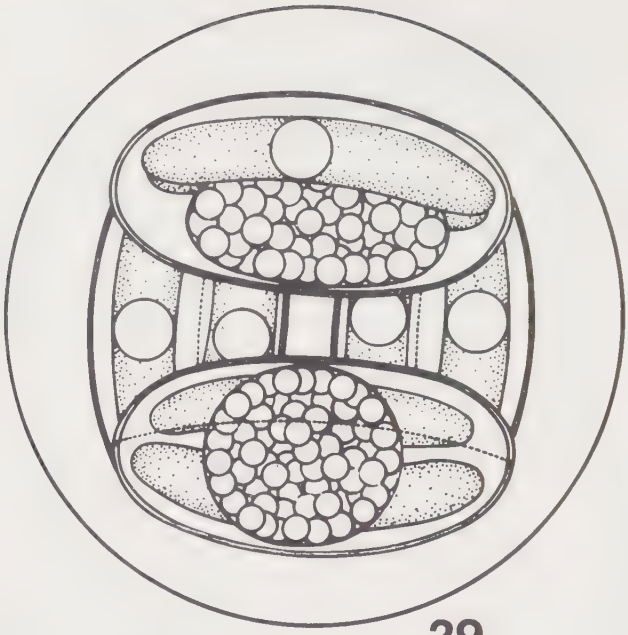

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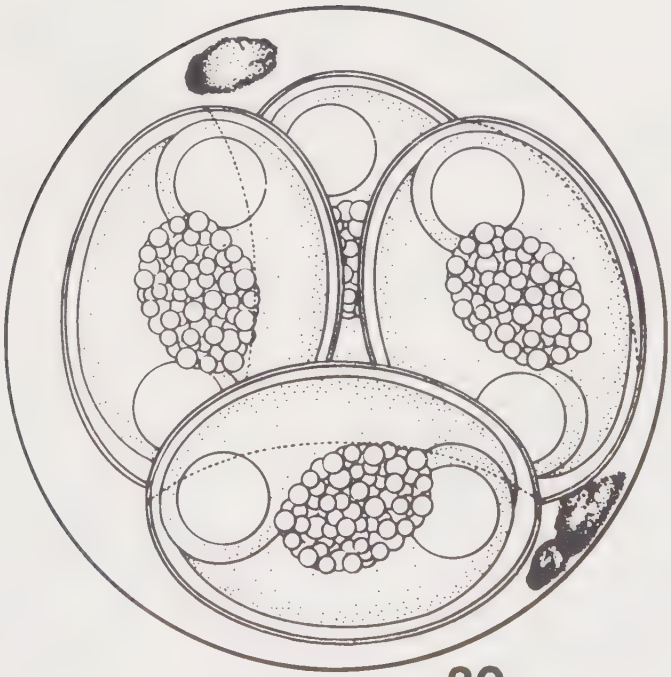

30

10 µm

caseosa (from Lom and Dyková 1982a); 29. *G. deguistii* (from Molnar and Fernando 1974); 30. *G. gadi* (from Fiebiger 1913; Odense and Logan 1976).

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